



REVIEW

Current status, biology, threats and conservation priorities of the Vulnerable Mediterranean monk seal

Alexandros A. Karamanlidis*

Pinniped Specialist Group, Species Programme, International Union for the Conservation of Nature (IUCN)

ABSTRACT: The Mediterranean monk seal *Monachus monachus* is one of the most endangered marine mammals on Earth. The species has made a notable recovery during the past 10 yr and is now considered Vulnerable by the International Union for the Conservation of Nature. Its global population comprises 3 subpopulations: 2 in the northeastern Atlantic Ocean and one in the eastern Mediterranean Sea. Global estimated abundance is 815–997 individuals, including 443–599 mature individuals; annual pup production averages 170.5. Over the past decade, increased research efforts have shed new light on various aspects of the species' biology and life history, including habitat and habitat use, vital rates, communication and genetics. The main threats to the species are (1) terrestrial and marine habitat loss and degradation that has or is resulting in the occupation of unsuitable habitat and limited prey availability, (2) negative interactions with fisheries that result in accidental entanglement or deliberate killings in response to damages to catches and/or fishing gear, (3) unpredictable threats, including cave collapses and mass mortality events and (4) pollution. Priority conservation actions for the species include (1) strengthening the legal framework for the protection of the terrestrial and marine habitat of the species, (2) effective protection of the species and its terrestrial and marine habitat, (3) scientific population and habitat monitoring, (4) rescue and rehabilitation of injured, orphaned and sick pups to increase neonatal survival rates, (5) public awareness and education, (6) monitoring and mitigating negative seal–fishery interactions and (7) expansion of the species' current geographic range in the Atlantic Ocean.

KEY WORDS: *Monachus monachus* · Pinnipeds · Conservation · Endangered species · Marine mammals · Population recovery

1. INTRODUCTION

The Mediterranean monk seal *Monachus monachus* is considered one of the most endangered pinniped species on Earth (Karamanlidis & Dendrinos 2015, Karamanlidis et al. 2019) and one of the 'evolutionarily distinct and globally endangered' mammals (Isaac et al. 2007). First described in 1779 by Johann Hermann as *Phoca monachus*, the Mediterranean monk seal and its closest relatives (i.e. the now-extinct Caribbean and the endangered Hawaiian monk seal) belong to the monachine tribe that was originally considered to

have evolved and diversified in the North Atlantic Ocean (Johnson et al. 2006, Karamanlidis et al. 2016a). However, recent examination of fossil evidence from New Zealand from the Pliocene suggests that monachine seals evolved in the Southern Hemisphere before moving northward and settling in the latitudes in which they are currently found (Rule et al. 2020). Furthermore, recent analysis of ancient DNA and examination of skull morphology (Scheel et al. 2014) suggests that Caribbean and Hawaiian monk seals do not belong to the same genus as the Mediterranean monk seal and that these species should there-

*Corresponding author: akaramanlidis@gmail.com

fore be classified as the new genus *Neomonachus* (i.e. *Neomonachus tropicalis* for the Caribbean monk seal and *N. schauinslandi* for the Hawaiian monk seal). As a result, the Mediterranean monk seal is currently the sole representative of the genus *Monachus*.

Mediterranean monk seals have been known to, and exploited by, humans for their flesh, blubber and skin since prehistoric times. Their remains have been found, for example, in the Vestibulo hall of the 'de Nerja' cave in Malaga, Spain, which was occupied by humans more than 10 000 yr ago (Morales-Pérez et al. 2019). The species also played an important cultural role in ancient Greece; a votive from the 6th–5th century BC that was recently discovered in the museum of Mycenae, Greece, clearly shows a Mediterranean monk seal (Panou & Dimitratos 2018). During historic times, commercial seal hunting and human persecution have been the main drivers for wiping out the large, open-beach-dwelling colonies of the species (González 2015). This intense anthropogenic pressure also led to a gradual change in the way terrestrial habitat was used by the Mediterranean monk seal (i.e. seals moved from open beaches to secluded, marine caves for resting and pupping, González 2015) and produced severe bottleneck(s) that significantly reduced genetic diversity (Gaubert et al. 2019). For most of the twentieth century, Mediterranean monk seal populations continued to decline, mostly as a consequence of human invasion into critical seal habitat and adverse interactions with fisheries, which ultimately resulted in the fragmentation into a handful of small, isolated subpopulations and the disappearance of the species from most of its historical range (Karamanlidis et al. 2016a). In the 1980s, concerted research and conservation actions were initiated in the main areas of the species' distribution in order to save the Mediterranean monk seal from extinction (Karamanlidis et al. 2016a).

At the turn of the previous century, the species was still considered to be on the brink of extinction and was therefore listed as Critically Endangered on the Red List of the International Union for the Conservation of Nature (IUCN) (Aguilar & Lowry 2008). In 2015, however, acknowledging signs of population recovery, the IUCN changed the global population status of the Mediterranean monk seal to Endangered (Karamanlidis & Dendrinos 2015), and in 2019, the eastern Mediterranean subpopulation of the species was also listed as Endangered (Karamanlidis et al. 2019). Over the last decade, conservation efforts for the species have intensified and the early signs of population recovery have become more common, thus creating a new conservation reality for the Medi-

terranean monk seal. This has now prompted a reassessment of the species' conservation status by the IUCN (Karamanlidis et al. 2023), which has made the compilation of updated, reliable data that can be used as background information to formulate effective research, management and conservation measures a research priority.

When the first efforts to save the Mediterranean monk seal were initiated, poor understanding of the species' status, biology and threats hampered its effective conservation (Johnson et al. 2006). Over time, several attempts have been carried out to compile the available information on the Mediterranean monk seal (e.g. Israëls 1992, González et al. 2006, Johnson et al. 2006, Karamanlidis et al. 2016a), thoroughly covering the available literature up to the year 2013. Since then, however, and following an increased interest in the fate of the species, research, management and conservation efforts have intensified and been carried out, more or less systematically, throughout almost the entire range of the Mediterranean monk seal. These efforts have been conducted using various methodologies, including:

- *In situ* monitoring of Mediterranean monk seal populations, where direct observations and/or indirect signs of presence were collected and recorded (e.g. Greece, Panou et al. 1993; Türkiye, Gücü et al. 2004).
- The development of autonomous monitoring (i.e. modified trail camera systems, Aparicio et al. 2016) and video surveillance systems that were installed in the main terrestrial habitat of the species and enabled the implementation of detailed photoidentification studies (e.g. Cabo Blanco, Fernández de Larrinoa et al. 2021; Madeira, Pires et al. 2023; Greece, Karamanlidis et al. 2021a; Türkiye, Beton et al. 2021, Saydam & Güçlüsoy 2023; Cyprus, Nicolaou et al. 2021).
- The use of time–depth recorders to identify foraging habitat and study diving behaviour (Fernández de Larrinoa et al. 2019).
- The use of citizen science data (e.g. in Madeira, the RED SOS Lobo Marinho Network, Pires et al. 2023; in Greece, the Hellenic Monk seal Rescue and Information Network, Adamantopoulou et al. 2023; in Türkiye, the AFBKA, Kırac et al. 2013).
- Genetic monitoring (e.g. Greece, Karamanlidis et al. 2021b).

More recently, efforts have been initiated to develop new techniques to study Mediterranean monk seals, e.g. using photogrammetry (Pierantonio & Gonzalvo 2019), acoustics (Charrier et al. 2017, 2023), social media (Kerametsidis et al. 2022) and eDNA (Valsecchi et al. 2022, 2023).

All these efforts have greatly advanced our understanding of the species. The main aim of this review is to summarize the most recent and important data about *M. monachus* in the hope that this will constitute the baseline knowledge needed to formulate effective research, management and conservation measures. This review (1) compiles only the most recent (i.e. 2013–2023) information on the distribution and status, and the biology and life history of the Mediterranean monk seal, (2) identifies threats likely to affect its persistence and (3) briefly summarizes the main conservation priorities and actions that have been carried out so far for the species.

This review uses the annotated bibliography of Karamanlidis & Johnson (2002) and the reviews of Johnson et al. (2006) and Karamanlidis et al. (2016a) as points of reference and examines only the most recent (i.e. 2013–2023) scientific literature (i.e. articles in peer-reviewed journals) in English as a source of information; information prior to 2013 was used only if no relevant information was published during the study period. Grey literature (i.e. books, book sections, conference proceedings, unpublished reports, websites) was also reviewed, but was usually excluded; only in some cases were unpublished sources of essential information also used. To identify this information, an exhaustive literature search was conducted using the online search engines Google Scholar, PubMed and Web of Science Core Collection, using as keywords the common and species-level scientific names of the Mediterranean monk seal, which resulted in the identification of 178 source materials (book sections, 5; conference proceedings, 73; journal articles, 72; unpublished reports, 21; web pages, 7). Handling of the search results was facilitated through the creation of a reference library ('Post 2013 MMS Library'; available upon request) in Endnote 20 (Clarivate Analytics) and a folder of publicly available .pdf files ($n = 97$; available upon request).

2. DISTRIBUTION AND POPULATION STATUS

The Mediterranean monk seal is the only resident pinniped species in the Mediterranean Sea. The species was once widely and continuously distributed throughout the entire Black and Mediterranean Seas and the archipelagos of the Canary, Madeira and Azores Islands, as well as the northwestern coast of Africa and the coast of the Iberian Peninsula in the northeastern Atlantic Ocean. Vagrants have been recorded in Senegal, the Gambia, the Cape Verde Islands and Atlantic France (Johnson et al. 2006, González

2015, Karamanlidis et al. 2016a) but the origin of these individuals is unknown. The assumption of a single metapopulation has been recently supported by genetic evidence (Gaubert et al. 2019). Following centuries of decline (Johnson et al. 2006, González 2015, Karamanlidis et al. 2016a), the current distribution of the Mediterranean monk seal includes 2 subpopulations in the northeastern Atlantic Ocean and one subpopulation in the eastern Mediterranean Sea (Karamanlidis et al. 2016a). Systematic monitoring efforts are currently being carried out throughout all main areas of the species' distribution, resulting in an overall detailed understanding of its distribution and demographic status. This understanding is better than a decade ago when the previous assessment of the conservation status of the Mediterranean monk seal by the IUCN was carried out (Karamanlidis & Dendrinos 2015).

2.1. Mediterranean monk seal subpopulations in the northeastern Atlantic Ocean

Systematic monitoring efforts for more than 25 yr provide a very detailed understanding of the distribution and demographic status of the Mediterranean monk seal in the northeastern Atlantic Ocean. Mediterranean monk seals have been extirpated throughout the largest part of their historical range in the region and survive only in 2 subpopulations in the Cabo Blanco Peninsula (Western Sahara and Mauritania) and the archipelago of Madeira (Portugal) (Johnson et al. 2006, Karamanlidis et al. 2016a). Joint analysis of extensive photo-identification and telemetry data has not found any recent evidence of movement between these subpopulations (Fernández de Larrinoa et al. 2021, Pires et al. 2023), and genetic evidence suggests that they have been isolated for some time now (Rey-Iglesia et al. 2021).

The Cabo Blanco Peninsula (also known as Ras Nouadhibou) is currently home to the largest aggregation of Mediterranean monk seals globally; the monk seals in this region have retained the social structure of a typical seal colony (Martínez-Jauregui et al. 2012). The terrestrial habitat of the species in the region is mainly confined to 3 pupping caves along a 1.5 km stretch of coastline at the 'Coast of Seals', while the marine habitat is mainly limited to 80 km north and south of the 3 important pupping caves, extending up to 12 nautical miles (nmi) offshore (Fernández de Larrinoa et al. 2021), although some juveniles may venture up to 25 nmi offshore (Fernández de Larrinoa et al. 2016). Following a mass die-off in 1997

that wiped out almost two-thirds of the colony (Johnson et al. 2006, Karamanlidis et al. 2016a), intense conservation efforts were initiated under the frame of an international action plan developed by the authorities of Spain, Mauritania, Portugal and Morocco, which has helped reverse the tide. The early signs of population recovery recorded at the beginning of the century have continued and allowed the Mediterranean monk seal colony in Cabo Blanco to recover now to its pre mass die-off size (Fernández de Larrinoa et al. 2021). Based on systematic photo-identification efforts, the Mediterranean monk seal subpopulation in Cabo Blanco is currently estimated to number approximately 350 individuals (Fernández de Larrinoa et al. 2021, Cedenilla et al. 2022), including 184 mature individuals. Annual pup production averages 70 pups (CBD Habitat unpubl. data in Karamanlidis et al. 2023). The Mediterranean monk seal subpopulation in Cabo Blanco is characterized by low (0.46) neonatal survival rates (i.e. from birth to 1st year), high fecundity rates, early breeding age in females and high adult survival rates (Fernández de Larrinoa et al. 2021).

In contrast to Mediterranean monk seals in the Mediterranean that have been in contact with humans since antiquity, the Mediterranean monk seal subpopulation in the archipelago of Madeira was first discovered in the 15th century; after its discovery, the subpopulation followed the familiar pattern of intense persecution by humans and a drastic reduction in population size (Biscoito 1988), which left it at the brink of extinction. In 1988, only 6–8 individuals remained, confined to the remote Desertas Islands (Marchessaux 1989). Since then, intense conservation efforts have helped the species recover, expanding its range and increasing slightly in size. The terrestrial habitat of the species currently consists of numerous marine caves on the Desertas Islands (Karamanlidis et al. 2004), but also on the main island of Madeira where suitable habitat is available, mainly around the northeastern part of the island (Karamanlidis et al. 2003, Pires et al. 2020). On the island of Madeira and the sub-archipelago of the Desertas Islands, 12 and 13 marine caves, respectively, are considered to be suitable for the Mediterranean monk seal; of these caves, 2 and 9 caves, respectively, are currently used by the species (Pires et al. 2020). The marine habitat in the archipelago is restricted to oligotrophic waters (Delgado 2007) on the shelf area around the Desertas Islands and the main island of Madeira, which is limited to only 743 km² (Fernández de Larrinoa et al. 2019). Systematic photo-identification studies testify that the Mediterranean monk seal

subpopulation in the archipelago of Madeira has grown 3- to 4-fold since the late 1980s and currently numbers 27 individuals, including 13 mature individuals. Annual pup production averages 3.5 pups (Pires et al. 2023). The Mediterranean monk seal subpopulation in the archipelago of Madeira is characterized by low neonatal (0.47) and high adult survival rates (0.98 for females and 0.90 for males) and low mean gross reproductive rates (0.31) (Pires et al. 2023). Female Mediterranean monk seals in Madeira reproduce for the first time at the age of 6, while by contrast, reproduction in the Mediterranean monk seal subpopulation in Cabo Blanco takes place as early as the age of 3 yr (Fernández de Larrinoa et al. 2021, Pires et al. 2023). This negative demographic parameter is believed to be associated with the limited availability of food sources (Pires et al. 2023). Despite the slight recovery, the Mediterranean monk seal subpopulation in Madeira is still extremely small and therefore very vulnerable, and it should be considered critically endangered; the population requires systematic and effective conservation efforts in order to persist (Pires et al. 2020). Recent genetic studies indicate that the Mediterranean monk seal subpopulation in the archipelago of Madeira is genetically depauperate and closely related to the Mediterranean monk seal subpopulation in Cabo Blanco (Dayon et al. 2020). Translocation of individuals from the latter should therefore be considered beneficial.

2.2. Mediterranean monk seal subpopulation in the eastern Mediterranean Sea

In the eastern Mediterranean Sea, systematic monitoring efforts have been carried out on a local and/or national level for more than 35 yr (e.g. Greece, Dendrinos et al. 2020; Türkiye, Kırac et al. 2013). Considering, however, the extent and the morphological characteristics of the eastern Mediterranean coastline and the great number of islands and islets in the region (Greece alone has more than 7500, Triantis & Mylonas 2009) as well as the fact that Mediterranean monk seals occupy the coastal waters of several countries (Johnson et al. 2006, Karamanlidis et al. 2016a, Bundone et al. 2019, 2023), it is easy to understand why estimating demographic parameters for the entire subpopulation or even on a national level is an extremely difficult (and inexact) task (Kurt & Gücü 2021, Pietroluongo et al. 2022b) and why actual seal numbers in the region remain largely unknown (Panou et al. 2023). Given the aforementioned limitations, it should be considered that our understanding

of the distribution and demographic status of the Mediterranean monk seal in the eastern Mediterranean Sea is less detailed than that of the species in the Atlantic Ocean.

In Greece, important Mediterranean monk seal population nuclei have been found and monitored throughout the country (e.g. Dendrinis et al. 2020). Only one of these population nuclei, the one at the island of Gyaros, appears to exhibit the demographic structure of a typical colony (Karamanlidis et al. 2013) as encountered in other pinnipeds. All the other population nuclei are smaller, consisting of aggregations of up to just a few dozen individuals. The results of all these monitoring efforts provide evidence that Mediterranean monk seals in Greece are expanding their range and increasing in numbers. In the central Ionian Sea, an increase in annual pup production and an expansion of terrestrial habitat has been recorded (Panou et al. 2022), while on a national level, the distribution of seals of all age categories and that of pups has increased between 2000 and 2020 by 12.5 and 185%, respectively (Adamantopoulou et al. 2023). This expansion has largely taken place in areas that are legally protected. The terrestrial habitat of the Mediterranean monk seal in Greece currently includes more than 500 caves that have been found to be occupied by the species and more than 100 caves that are used for pupping (Dendrinis et al. 2020). The marine habitat of the Mediterranean monk seal in Greece is considered to include almost the entire coastline of the country up to a depth of 200 m (Adamantopoulou et al. 2023). Using an approach based on a pup multiplier (Karamanlidis 2024), the number of Mediterranean monk seals in Greece has been estimated at 337–450 individuals, including 187–262 mature individuals (Karamanlidis et al. 2023). Annual pup production averages 75 pups (Karamanlidis & Dendrinis 2023). Annual pup survival until weaning in Greece is suspected to be generally higher (i.e. 0.7), according to unpublished reports by MOm¹ and Karamanlidis & Dendrinis², than that recorded in the Atlantic subpopulations, which is most likely because

lactating females and their pups have a higher number of suitable caves to choose from when seeking refuge from severe weather conditions.

In Türkiye, the Mediterranean monk seal remains extinct in the Black Sea, where it is assumed to have been extirpated around the end of the previous century (Kıraç & Savas 1996). A recent review of the occurrence of the species in neighbouring Bulgaria similarly places the last record of a Mediterranean monk seal in the Black Sea at the Silistar region on 8 December 1996 (Boev 2018). In the Sea of Marmara, Mediterranean monk seals have been reported recently from the westernmost and central parts of the southern coastline, mainly in and around Karabiga, the Kapıdağ Peninsula and the Marmara Islands archipelago (Inanmaz et al. 2014, Kıraç & Ververi 2018). Several Mediterranean monk seal population nuclei have been identified and monitored recently all along the coasts of the Aegean Sea and the northeastern Mediterranean coast of Türkiye, including, for example, the island of Gökçeada in the northern Aegean Sea (Dede et al. 2019), Gökova Bay (Saydam & Güçlüsoy 2023) and the northeastern Mediterranean coast of Türkiye (Kurt & Gücü 2021). The results of these studies indicate that overall seal sighting frequencies (SAD—AFAG unpubl. data in Karamanlidis et al. 2023) and the area occupied by Mediterranean monk seals in Türkiye have been increasing recently (Kıraç & Savaş 2019). A notable exception to this trend is the population nucleus in the northeastern Mediterranean coast of Türkiye, where mortality rates have increased, fecundity rates have decreased and no signs of recovery are discernible (Kurt & Gücü 2021). As in Greece, the terrestrial habitat of the Mediterranean monk seal in Türkiye currently includes numerous marine caves all along the coastline of the country (Kıraç et al. 2013, Kıraç & Savaş 2019); in the Cilician Basin region of southern Türkiye for example, 39 marine caves were discovered, including 3 that were used for pupping and 16 that were actively used at the time of the survey (Gücü et al. 2004). The marine habitat of the species is considered to include most of the coastline of the country up to a depth of 200 m. Based on expert judgement and an approach based on annual pup counts, the number of Mediterranean monk seals in Türkiye has been estimated at 76–140 individuals, including 42–120 mature individuals (Karamanlidis et al. 2023). Annual pup production averages 17 pups (M. Ok & C. O. Kıraç unpubl. data in Karamanlidis et al. 2023; note that these estimates include the northern part of the island of Cyprus).

Following eradication in the previous century (Nicolaou et al. 2021), an increasing number of sight-

¹MOm (2008) Unpublished final report on the monitoring of the status of the population of the monk seal, in Karpathos and Saria. MOm/Hellenic Society for the Study and Protection of the Monk Seal, Athens

²Karamanlidis AA, Dendrinis D (2012) A glimpse into the past, a prospect for the future: studying the status and behavior and promoting conservation of Mediterranean monk seals at the island of Gyaros. Unpublished final report to the National Geographic Grant #W178-11. MOm/Hellenic Society for the Study and Protection of the Monk Seal, Athens

ings, births and interactions with small-scale fisheries (Nicolaou et al. 2021, Beton et al. 2021, Papageorgiou et al. 2023) indicate that the species has effectively been re-established at the island of Cyprus. Using an approach based on a pup multiplier (Karamanlidis 2024) and annual pup counts, the number of Mediterranean monk seals in the Republic of Cyprus is estimated at 13–18 individuals, including 7–10 mature individuals (Karamanlidis et al. 2023). Annual pup production averages 3 pups (Department of Fisheries and Marine Research Cyprus unpubl. data in Karamanlidis et al. 2023).

2.3. Remainder of the population

Beyond Greece, Türkiye and Cyprus, the extralimital appearances of Mediterranean monk seals in the eastern Mediterranean that were recorded at the beginning of the century (Karamanlidis et al. 2016a) have continued and increased. Seals have also been recently recorded or detected in the central and western part of the Mediterranean Sea (Bundone et al. 2019, Valsecchi et al. 2022, 2023), which highlights the importance of also protecting critical Mediterranean monk seal habitat in areas where the species has been extirpated (Bundone et al. 2019).

More specifically, in the eastern Mediterranean Sea, Mediterranean monk seals have been recorded recently in Lebanon, Palestine and Israel. In Lebanon, several sightings have been recorded (Bariche & Crocetta 2016), including one in 2015 that involved a pregnant adult female Mediterranean monk seal that was deliberately killed. In Israel, several sporadic sightings of Mediterranean monk seals have been recorded during the last decade (Roditi-Elasar et al. 2021). The most recent sightings in Israel and the Gaza Strip, Palestine, in 2023 are of an adult female that had been previously closely monitored in Türkiye (Abd Rabou 2023, Abd Rabou et al. 2023). Despite these sightings, and considering that (1) no successful births (i.e. pup surviving 2 mo post-partum) have been recorded, (2) suitable pupping habitat appears to be limited (Bundone et al. 2016) and (3) anthropogenic pressure is high, the species should not be considered to have been effectively re-established yet in this part of the eastern Mediterranean Sea.

On the southern coast of the Mediterranean Sea, Mediterranean monk seals were recorded in 2012 for the first time in Libya in over 40 yr (Alfaghi et al. 2013); this observation has been followed by the finding of 2 dead individuals in 2023 (I. E. Alfaghi pers. comm.).

In the central part of the northern Mediterranean, several observations of Mediterranean monk seals have been recorded recently in the Adriatic Sea and in Italy. In Albania, numerous sightings and evidence of cave use have been recorded recently (Bundone et al. 2021, 2022); given the presence of suitable habitat for the species, especially in the southern part of the country (i.e. mainly around the National Marine Park of Karaburun-Sazan) and the birth of a pup in 2019 that survived the first 2 mo of its life (Eastern Adriatic Monk Seal Project 2019), the species should now be considered to be effectively re-established in Albania, at least from the border of Albania to Greece north to the bay of Vlorë. However, systematic monitoring efforts in the country should be continued in order to establish whether this recovery persists. In Montenegro, a total of 14 monk seal sightings were recorded between 1985 and 2010 (Panou et al. 2017), and monitoring efforts have been carried out throughout the country. In 2023, a sub-adult Mediterranean monk seal was recorded in Montenegro for the first time in 55 yr (<https://www.youtube.com/watch?v=Eo4dPx58eLM>). Monitoring efforts have also been carried out in Croatia (Bundone et al. 2013) and have revealed the presence of the species as recently as 2023 (Bundone et al. 2013, Eastern Adriatic Monk Seal Project 2019, Anđelković 2023). Following a spate of observations up to 2010 (Mo 2011), Mediterranean monk seals have been recorded recently in Italy in the Gulf of Venice in the northwestern Adriatic Sea (Borgo et al. 2014), in southern Apulia (Fioravanti et al. 2020, Zangaro et al. 2020, Bundone et al. 2023) and in Sicily (Valsecchi et al. 2022). In addition, eDNA studies have detected Mediterranean monk seals in the Tyrrhenian Sea and in the Pelagie archipelago in the Strait of Sicily (Valsecchi et al. 2022). Despite these sightings, the conservation status of the Mediterranean monk seal in the country has been characterised as Data Deficient (Rondinini et al. 2022).

Again, considering that with the exception of Albania, successful reproduction has not been recorded in any of the aforementioned countries, the Mediterranean monk seal should not be considered to be effectively re-established on the central shores of the northern and southern Mediterranean Sea. A conservative expert judgement has placed the total number of individual seals and pups living in these areas at 10 and 2 individuals, respectively (Karamanlidis et al. 2023). Consequently, the Mediterranean monk seal should be considered to still be extinct in Algeria, Bosnia and Herzegovina, Bulgaria, Cabo Verde, France, Gambia, Georgia, Malta, Monaco, Morocco,

Table 1. List of original Mediterranean monk seal range countries indicating the current status of the species

| Country | Presence |
|--|---|
| Albania | Extant |
| Algeria | Extinct post-1500 |
| Bosnia and Herzegovina | Extinct post-1500 |
| Bulgaria | Extinct post-1500 |
| Cabo Verde | Extinct post-1500 |
| Croatia | Possibly extinct, recent sightings, no confirmed successful pupping |
| Cyprus | Extant |
| Egypt | Possibly extinct, no recent sightings |
| France | Extinct post-1500 |
| Gambia | Extinct post-1500 |
| Georgia | Extinct post-1500 |
| Greece | Extant |
| Israel | Possibly extinct, recent sightings, no confirmed successful pupping |
| Italy | Possibly extinct, recent sightings, no confirmed successful pupping |
| Lebanon | Possibly extinct, recent sightings, no confirmed successful pupping |
| Libya | Possibly extinct, recent sightings, no confirmed successful pupping |
| Malta | Extinct post-1500 |
| Mauritania | Extant |
| Monaco | Extinct post-1500 |
| Montenegro | Possibly extinct, recent sighting, no confirmed successful pupping |
| Morocco | Extinct post-1500 |
| Portugal (mainland and Azores archipelago) | Extinct post-1500 |
| Portugal (Madeira archipelago) | Extant |
| Romania | Extinct post-1500 |
| Russian Federation | Extinct post-1500 |
| Senegal | Extinct post-1500 |
| Slovenia | Extinct post-1500 |
| Spain | Possibly extinct, detection through eDNA, no recent sightings |
| Syrian Arab Republic | Possibly extinct, no recent sightings |
| Tunisia | Extinct post-1500 |
| Türkiye | Extant |
| Ukraine | Extinct post-1500 |
| Western Sahara | Extant |

Portugal (continental part and archipelago of Azores), Romania, Russia, Senegal, Slovenia, Spain (including the Canary Islands in the Atlantic Ocean), Tunisia and Ukraine (Table 1, Fig. 1).

In summary, Mediterranean monk seal populations have been recovering throughout the largest part of their range during the past decade (2013–2023). However, because of its small global population, *Monachus monachus* should still be considered one of the most endangered pinniped species in the world. Its current terrestrial habitat includes hundreds of marine caves, primarily along the coastlines of Cabo Blanco and the archipelago of Madeira in the north-eastern Atlantic Ocean and the coastlines of Greece, Türkiye, Cyprus and Albania in the eastern and central Mediterranean Sea. The marine habitat of the species throughout its range (with the exception of Cabo Blanco, where the species occupies shallower marine habitat) extends to the 200 m isobath. The global abundance of the Mediterranean monk seal

has been estimated at 815–997 individuals, including 443–599 mature individuals (Karamanlidis et al. 2023) and annual pup production averages 170.5 pups (CBD Habitat, Department of Fisheries and Marine Research Cyprus, MOm, IFCN, SAD–AFAG unpubl. data in Karamanlidis et al. 2023). Based on the most recent data available, and according to criterion D1 (i.e. number of mature individuals), the IUCN considers the conservation status of *Monachus monachus* as recently improved and has changed the species' status from Endangered to Vulnerable (Karamanlidis et al. 2023).

3. BIOLOGY

Mediterranean monk seals are medium-sized phocids that reach 2.3–2.8 m in length and weigh 240–300 kg (Littnan et al. 2018). The species is characterized by morphological differences between

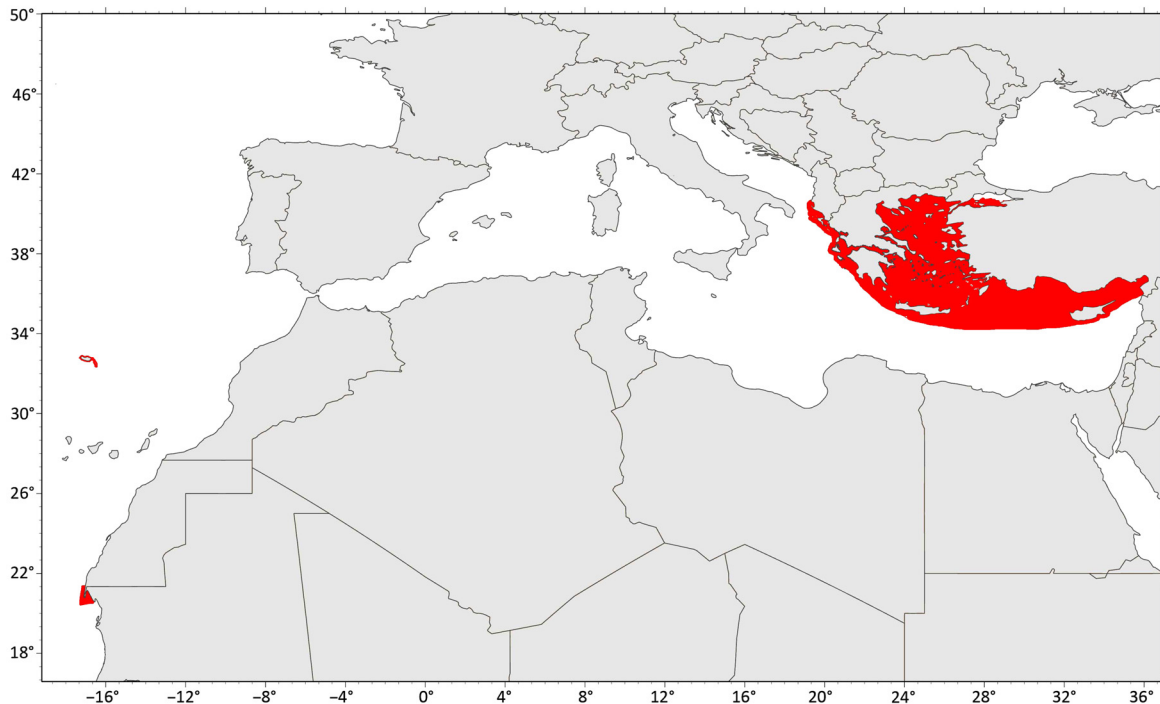


Fig. 1. Global range of the Mediterranean monk seal

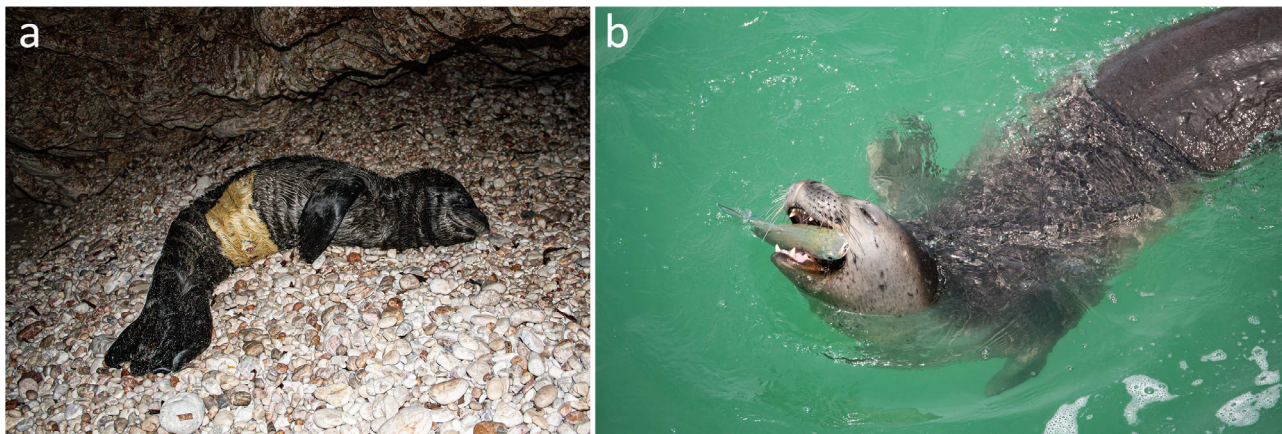


Fig. 2. (a) A female Mediterranean monk seal pup resting inside a cave in Greece. The black lanugo fur and the sexually dimorphic, white-yellowish patch on the ventral side are visible. Newborn pups are approximately 1 m long. (b) A subadult Mediterranean monk seal feeding in Cabo Blanco. The darker dorsal and lighter ventral side are visible. Subadult Mediterranean monk seals are approximately 1.5–2 m long (© A. A. Karamanlidis and MOm)

development stages (Badosa et al. 1998): pups are born with dark lanugo fur and a sexually dimorphic, white-yellowish patch on the ventral side (Fig. 2). Following the first moult, at the age of approximately 8–10 wk (Samaranch & González 2000, Badosa et al. 2006), seals grow into a generally brown or greyish pelage with a lighter underside (Fig. 2). Adult females keep this pelage for life, whereas upon reaching sexual maturity, males grow into a uniformly black

pelage with a white patch on the ventral side (Samaranch & González 2000). The white patch is of the same shape as the one they had as pups. This distinct feature of the species is used as a tool to monitor male Mediterranean monk seals throughout their life (Cedenilla et al. 2017). Attainment of sexual maturity in male Mediterranean monk seals occurs at approximately the age of 4–6 yr (Cedenilla et al. 2017, Koemtzopoulos et al. 2022, Pires et al. 2023). Sexual

maturity in females is attained in the Cabo Blanco subpopulation as early as at the age of 3 (Fernández de Larrinoa et al. 2021); by contrast, in the archipelago of Madeira, sexual maturity is attained the earliest at the age of 6 (Pires et al. 2023). Female Mediterranean monk seals can give birth in consecutive years (Pastor & Aguilar 2003). Cedenilla et al. (2022) describe the first 2 cases of polythelia with possible polymastia in 2 breeding females from the archipelago of Madeira and Cabo Blanco, and Graïc et al. (2024) describe, for the first time, the brain of a Mediterranean monk seal.

Pupping in the Mediterranean monk seal subpopulations in the eastern Mediterranean Sea and the archipelago of Madeira is rather synchronous, occurring mainly in October and November. This has been the case for the majority of pups born in Greece after 1990 (MOM unpubl. data in Karamanlidis et al. 2023), for 11 pups born in the Cilician Basin (Gücü et al. 2004) and 6 pups born on the coasts of İzmir and Muğla in Türkiye (SAD–AFAG unpubl. data in Karamanlidis et al. 2023) and for the majority of pups born in Madeira from 1990 onwards (Pires et al. 2023). By contrast, in the Cabo Blanco subpopulation births can take place throughout the year (Gazo et al. 1999, Fernández de Larrinoa pers. comm. in Karamanlidis et al. 2023).

3.1. Habitat and habitat use

As with all seals, Mediterranean monk seals require specific habitat on land and at sea in order to fulfil certain biological functions. The locations that Mediterranean monk seals use for pupping and resting have changed from open beaches to secluded beaches inside remote, difficult-to-access marine caves that offer protection against humans and other predators (González 2015, Karamanlidis et al. 2016a). Most marine caves currently used by Mediterranean monk seals throughout their range possess a set of common geophysical characteristics that include, among other features, an entrance corridor and a dry surface or area where seals haul out (Karamanlidis et al. 2004, Dendrinos et al. 2007b) (Fig. 2). These features have been also confirmed recently from southwestern Türkiye (Saydam & Güçlüsoy 2023) and are generally used as guidelines in efforts to identify and protect critical habitat for the species. During the last decade, however, new evidence has been complementing our understanding of the features associated with the type of habitat used by Mediterranean monk seals. In the Ionian Sea, evidence collected recently

indicates that caves that were traditionally considered ‘sub-standard’ (i.e. marine caves having only underwater entrances and/or no haul-out area) are also used by the species for resting (Gonzalvo et al. 2022). This is in accordance with previous observations from Türkiye (Johnson et al. 2006) and indicates that even such sub-standard habitat may provide important resting opportunities for this endangered species. In areas where suitable resting and/or pupping habitat is limited (e.g. Israel), conservationists have been suggesting that underwater caves be included in the habitat assessment of the species (Roditi-Elasar et al. 2021).

Seal preferences regarding the selection and use of terrestrial habitat are influenced by numerous parameters, including, for example, changes in the internal morphology of a cave (e.g. Cabo Blanco, González et al. 1997) and/or the state of the tide (Pires et al. 2007) (only in the Atlantic subpopulations, as tides in the Mediterranean are negligible). Human activity near caves (e.g. Türkiye) also appears to influence usage: marine caves close to areas of intense human activity may be abandoned, whereas caves in marine protected areas are more likely to be used (Kurt et al. 2018). Mediterranean monk seal activity in and around the pupping caves in the eastern Mediterranean Sea and the archipelago of Madeira is highest in autumn and winter and coincides with the pupping season of the species (Johnson et al. 2006, Karamanlidis et al. 2016a); these activity patterns have been recorded recently in the Cyclades Islands in the Aegean Sea, Greece (Karamanlidis et al. 2021a), and in the Bay of Gökova on the southwestern coast of Türkiye (Saydam & Güçlüsoy 2023). Furthermore, Mediterranean monk seals in Türkiye use marine caves mainly during the late afternoon and rest overnight, leaving the caves early the next morning (Kurt et al. 2018, Saydam & Güçlüsoy 2023).

Life in the most important pupping caves during the pupping season is characterized by the presence and interactions between breeding females and their pups; adult males in the eastern Mediterranean appear to use the marine caves during this time less frequently (Karamanlidis et al. 2021a, Saydam & Güçlüsoy 2023). Mediterranean monk seals remain in the important pupping caves for 3–4 mo, highlighting the importance of this critical habitat for the survival of the species. This time is split between periods of pup attendance and regular foraging trips of the breeding females (Gazo & Aguilar 2005, Aguilar et al. 2007, Karamanlidis et al. 2021a), which is in marked contrast to the closest relative of the species, the Hawaiian monk seal, where females generally do not

leave their pups unattended and fast (or feed rarely) during lactation (Littnan et al. 2018). Upon return to the cave, mothers and pups interact intensively (Karamanlidis et al. 2013). Recent studies in Greece (Karamanlidis et al. 2021a) and Türkiye (Saydam & Güçlüsoy 2023) show that when breeding females return from foraging trips, they call their pups and often interact by nuzzling each other's nose and face, in accordance with previous observations from Cabo Blanco (Aguilar et al. 2007). Occasionally, the approach of a non-filial pup, especially in the early days post-partum, may lead to visible aggressive interactions (Karamanlidis et al. 2021a). As in Cabo Blanco (Aguilar et al. 2007), fostering and allosuckling have now also been recorded in Greece (Karamanlidis et al. 2013). When using the terrestrial habitat during storms, breeding females have been observed to actively try to protect their pups from surging waves by placing their bodies between the sea and their pups or by holding them (Gazo et al. 2000, Beton et al. 2021, Karamanlidis et al. 2021a). Following parturition, the percentage of time spent in this critical habitat decreases gradually as pups develop towards independence (Gazo & Aguilar 2005, Karamanlidis et al. 2021a). Pups enter the water and begin diving during their first week of life (Gazo et al. 2006, Karamanlidis et al. 2010, 2021a).

High pup mortality has been associated with Mediterranean monk seal parturition in marine caves (Gazo et al. 2000). It is considered the primary constraint on the population growth rate at Cabo Blanco (Fernández de Larrinoa et al. 2021) and is a contributing factor to the slow recovery of the Madeira subpopulation (Pires et al. 2023), and to the overall precarious conservation status of the species (Karamanlidis & Dendrinis 2015, Karamanlidis et al. 2019). In an effort to deal with the issue of limited availability of suitable habitat, conservationists in Türkiye (Saydam et al. 2022) and Cyprus have been recently experimenting, successfully, with the creation of artificial habitat for the Mediterranean monk seal (i.e. construction of an artificial dry platform in Türkiye, restoring collapsed caves in the Republic of Cyprus). However, for the successful recovery of the species, it is generally believed that a return to more suitable habitat, e.g. open beaches, may be necessary (Karamanlidis et al. 2016a, Fernández de Larrinoa et al. 2021). Recent observations indicate that this might be occasionally happening. Dendrinis et al. (2022) describe 6 cases of female Mediterranean monk seals and their pups in Greece using open beaches. These observations are regarded as another sign of the species' recovery in Greece and as an expression of

breeding females trying to reduce intraspecific competition for space in pupping caves (Karamanlidis et al. 2021a). These observations are in accordance with previous and current observations from the archipelago of Madeira (Pires et al. 2023) and Greece (Dendrinis et al. 2008, Karamanlidis et al. 2010).

The life of the Mediterranean monk seal in the marine realm is generally restricted to the area between the shoreline and the 200 m isobath. In the Cabo Blanco and the eastern Mediterranean monk seal subpopulations, maximum dive depths of 78 and 100, and 191 and 123 m for (rehabilitated) females and males, respectively, have been recorded (Gazo & Aguilar 2005, Dendrinis et al. 2007a, MOm unpubl. data and P. Fernandez de Larrinoa pers. comm. in Karamanlidis et al. 2023). Recent studies in the archipelago of Madeira indicate, however, that Mediterranean monk seals can dive deeper than previously assumed, as maximum dive depths of 429 m for a breeding female and 393 m for an adult male have been recorded. However, most recorded dives of the species in the archipelago of Madeira were shallow (i.e. <50 m) and almost always within the 200 m isobath (Fernández de Larrinoa et al. 2019, Pires et al. 2020).

The ability of the Mediterranean monk seal to travel extensively, covering straight distances of up to 300 km has been thoroughly documented (Alfaghi et al. 2013, Fernández de Larrinoa et al. 2016, Roditi-Elasar et al. 2021, Kurt & Gücü 2021). Mobility of female (16.3–245 km) Mediterranean monk seals in the eastern Mediterranean appears to be higher than that of male Mediterranean monk seals (37.5–101 km) (Kurt & Gücü 2021), which is consistent with the assumption of female dispersal resulting from genetic studies of the species (Karamanlidis et al. 2021b).

Mediterranean monk seals use marine habitat not only for feeding (Fig. 2), but also for resting. This behaviour is similar to that observed in other captive and free-ranging true seals and highlights the importance of prioritizing habitat conservation actions in the marine environment as well (Karamanlidis et al. 2017).

3.2. Communication

Preliminary studies on the communication of the Mediterranean monk seal indicate that the species has a diverse vocal repertoire. Regarding air-borne vocalizations, 5 distinct call types have been identified (i.e. bark, chirp, grunt, short scream and scream; Charrier et al. 2017), prompting efforts to develop

new monitoring tools for the species based on individual identification through acoustics. Underwater vocalization also appears to be diverse; 'chin-up' calls (Asso et al. 2022) as well as 18 different types of harmonic, noisy and pulsative calls (Charrier et al. 2023) have been recorded in Greece. In addition, the sonic environment around important pupping caves has been investigated in Greece, indicating that noise levels around critical habitats may be high due to anthropogenic activities. This level of sound might not only impact communication among individuals, but also their survival, as chronic noise can induce physiological stress (Charrier et al. 2023).

3.3. Feeding

The Mediterranean monk seal is generally regarded as an opportunistic predator that forages primarily on the continental shelf, with a preference for fishes, crustaceans and cephalopods (Johnson et al. 2006, Karamanlidis et al. 2016a). Recent studies using various methodologies (e.g. stable isotopes, Karamanlidis et al. 2014; stomach content analysis, Karamanlidis et al. 2011, Tonay et al. 2016) have confirmed the mainly coastal diet of the species (Karamanlidis et al. 2014) and the importance of fishes, especially of the Family Sparidae (Tonay et al. 2016, Ríos et al. 2017, Bundone et al. 2022) and of the cephalopod *Octopus vulgaris* (Tonay et al. 2016, Kırac & Ok 2019) in the diet of the species. Marine turtles (i.e. loggerhead *Caretta caretta* and green turtles *Chelonia mydas*) do not seem to be as unusual of a prey item as previously assumed and have been recorded recently in the diet of the species on several occasions (e.g. Greece, Quintano & Chatzipavlis 2023; Türkiye, Tonay et al. 2016, Kırac & Türkozan 2023; northern Cyprus, Snape et al. 2022). In general, Mediterranean monk seals have been found to prey on fish that are often targeted by small-scale fisheries (Hernandez-Milian et al. 2018) and to consume species of commercial importance, such as monkfish *Lophius* spp. and hake *Merluccius* spp. Mediterranean monk seals have now been confirmed to be able to successfully feed on their own in the wild as early as 5 mo of age (Kırac & Ok 2019).

3.4. Parasites and zoonoses

The list of parasites of the Mediterranean monk seal has been extended to include the mite *Orthohalarachne diminuta* (Arachnida: Halarachnidae), the flatworm *Braunina cordiformis* (Trematoda: Braunini-

dae) (Danyer et al. 2017) and the hookworm *Uncinaria hamiltoni* (Nematoda: Ancylostomatidae) (Komenou et al. 2021). Regarding zoonoses, special attention should be given to the recent finding of a monk seal pup that was found along the southern Adriatic Italian coast and died due to co-infection with cetacean morbillivirus (CeMV) and *Toxoplasma gondii* (Mazzariol et al. 2021). CeMV infection has been reported previously in Mediterranean monk seals and harbour seals *Phoca vitulina* (Van Bressemer et al. 2014), and *T. gondii* is an emerging threat to the health and conservation of the Hawaiian monk seal (Barbieri et al. 2016). The possibility that Mediterranean monk seals can also be affected by the pox virus should not be disregarded; poxvirus is rarely fatal but may cause outbreaks with high morbidity under stressful conditions (e.g. low immune status, limited food availability) (Cihan et al. 2008).

3.5. Genetics

Recent Mediterranean monk seal genetic research has focused on mitochondrial DNA (e.g. Karamanlidis et al. 2016b, Gaubert et al. 2019, Rey-Iglesia et al. 2021), nuclear DNA (e.g. Dayon et al. 2020, Karamanlidis et al. 2021b, Salmona et al. 2022) and genes of the immune-related major histocompatibility complex (Gaughran et al. 2015) and provided valuable, new insights into the biology and life history of the Mediterranean monk seal. All studies have concluded that following severe population bottlenecks and population declines or habitat loss and fragmentation, the Mediterranean monk seal has suffered a severe loss in genetic diversity over the last few centuries and is currently one of the most genetically depauperate mammals on Earth (Karamanlidis et al. 2016b). In addition, Mediterranean monk seals also show high levels of inbreeding (Karamanlidis et al. 2021b, Salmona et al. 2022). These facts, along with the small global population of the species, are all traits of critically endangered species and suggest that despite recent evidence of demographic recovery, there is no reason for complacency (Karamanlidis et al. 2021b). Conservation efforts to protect the Mediterranean monk seal need to continue if the species is to persist.

4. THREATS

Mediterranean monk seals have a long history of negative interactions with humans that has led the species to its current precarious conservation status.

Previously, exploitation for subsistence needs and commercial harvest played a significant role in the decline of the species (Johnson et al. 2006, González 2015, Karamanlidis et al. 2016a), while more recently, habitat loss, deterioration and fragmentation, and negative interactions with fisheries have taken their toll (Johnson et al. 2006, Karamanlidis et al. 2016a). Given that Mediterranean monk seal populations are now too small to be commercially exploited, the scientific consensus (Karamanlidis et al. 2023) is that Mediterranean monk seals are currently threatened mainly by (1) terrestrial and marine habitat loss and degradation that has been or is being caused by increased human pressure (including tourism activities), (2) negative interactions with fisheries (including aquaculture) that include accidental entanglement as well as deliberate killings for perceived or actual damages to catches and/or fishing gear, even in countries and areas where the species is legally protected, (3) unpredictable threats and (4) pollution. The severity of each threat varies among geographic locations and Mediterranean monk seal subpopulations.

4.1. Habitat loss and degradation

Despite the establishment of numerous protected areas throughout its range, anthropogenic pressure leading to loss or degradation of critical terrestrial and marine habitat has been and still remains an important threat to the survival of the Mediterranean monk seal, both in areas where the species still exists as well as in areas where the species is expected or hoped to recover.

Following high anthropogenic pressure in the past and the consequent terrestrial and marine habitat loss and degradation, Mediterranean monk seals in the northeastern Atlantic Ocean have been confined to a very small portion of their original range, which in itself (i.e. the limited geographic range and isolation) is a threat to the survival of the species in the region (Böhm et al. 2016, Brauer & Beheregaray 2020). In addition, terrestrial habitat loss and degradation has forced Mediterranean monk seals in the northeastern Atlantic to rest and give birth in a small number of marine caves, which has been associated with high pup mortality. This fact is considered the primary constraint on the population growth rate at Cabo Blanco (Fernández de Larrinoa et al. 2021), is a contributing factor to the slow recovery of the Mediterranean monk seal subpopulation in Madeira (Pires et al. 2023) and might constrain future population growth. In addition to terrestrial habitat degradation and loss,

marine habitat degradation in the archipelago of Madeira through overfishing and coastal development has resulted in chronically limited prey resources, which is the primary factor responsible for the slow recovery of the local Mediterranean monk seal subpopulation (Pires et al. 2020, 2023). Tourism activities at sea in the archipelago of Madeira are also a disturbance to Mediterranean monk seals if not conducted properly (Pires et al. 2020). Despite effective protection of the most critical terrestrial and marine habitat in the region, the limited range and isolation of the Mediterranean monk seal subpopulations in the northeastern Atlantic has prompted conservationists to advocate and initiate re-introduction efforts to expand the range of the species in order to reduce the probability of the local extinction of the species (see Section 5).

In the eastern Mediterranean Sea, increasing anthropogenic pressure leading to terrestrial and marine habitat loss and degradation remains the main threat to Mediterranean monk seals (Johnson et al. 2006, Karamanlidis et al. 2016a). With overfishing (Bearzi et al. 2006) and coastal development (Gibson et al. 2007) increasing throughout the Mediterranean, so does the anthropogenic pressure on the species, and new conservation challenges are arising. In Greece, for example, the recent development of 'monk seal tourism' could develop into a new threat to the species if not conducted properly. In areas such as the islets of Lichadonisia in the Central Aegean and the Formicula islet in the inner Ionian Sea, tourists have been recorded trying to spot seals and often also to interact with them and/or visit their resting and pupping caves. Research has shown that Mediterranean monk seal activity at sea, especially that of subadults, is negatively affected by such activities (Mpougas et al. 2019), and therefore specific interaction guidelines have been issued (MOM 2022). In Türkiye, the construction of a terminal in Yeşilovacık has severely impacted critical monk seal habitat (Ok et al. 2019), and in the northeastern Mediterranean coast of the country, the species' recovery has been impacted by industrial development along coastal habitats (Kurt et al. 2017). Anthropogenic pressure on critical habitat is currently accentuated through the increase of tourism and has been recorded even in protected areas, such as the Olympos Beydağları National Park and the Kaş-Kekova Special Environmental Protection Area. Disturbance of critical Mediterranean monk seal habitat by boat excursions, SCUBA divers and tourists entering marine caves appears to have been increasing during the last decade and is now considered a threat to the species (Pires et al. 2020,

Kurt & Gücü 2021, SAD—AFAG unpubl. data in Karamanlidis et al. 2023). In areas where the species is expected or hoped to recover (e.g. Israel, Roditi-Elasar et al. 2021), increased human activity near critical terrestrial habitat might impede population recovery. With human populations and coastal activities increasing throughout the range of the species, there are corresponding increases in this type of threat to the species' habitat.

4.2. Negative interactions with fisheries

Monitoring negative interactions with fisheries in the eastern Mediterranean has been the focus of Mediterranean monk seal research, management and conservation efforts for a long time (Johnson et al. 2006, Karamanlidis et al. 2016a). It is now clear that negative interactions with fisheries in the past also played a significant role in the plight of the Mediterranean monk seal in Cabo Blanco, where these actions resulted in numerous cases of by-catch in gill-nets and bottom trawl nets, a decrease in observations of seals on open beaches and exposed rocks and an increase of seals hauling out in caves (González & Fernández de Larrinoa 2013). In order to protect the largest aggregation of Mediterranean monk seals worldwide, a no-fishing zone around the primary caves used by Mediterranean monk seals in Cabo Blanco was established in 1993 (González et al. 2006) and a marine—coastal reserve named 'Costa de las Focas' to protect the main pupping caves and vicinity was established in 2001.

Negative interactions with fisheries continue to play a role in the conservation of the Mediterranean monk seal throughout its range. In the archipelago of Madeira, negative interactions with fisheries (including aquaculture) (Karamanlidis et al. 2023), particularly with fishing traps, are considered to be low and restricted to coastal fisheries (Dinis et al. 2016, Martín et al. 2019), but fishermen still have a reluctant attitude towards the species, making information and awareness campaigns necessary. The potential deliberate killing of male seals in this small, recovering subpopulation is an issue of rising concern (Pires et al. 2020, 2023). Negative interactions with fisheries (Karamanlidis et al. 2008) also continue to be a major problem for the species in Greece, where studies have been carried out both on a local (e.g. Lipsi Island, northwestern Greece, Rios et al. 2017) and national scale (Karamanlidis et al. 2020). These efforts indicate that the deliberate killing of Mediterranean monk seals, mainly by fishermen, is still one of the most

important sources of (adult) Mediterranean monk seal mortality in the country (Dendrinis et al. 2020) and has been responsible for at least 110 seal deaths since 1990 (MOM unpubl. data in Karamanlidis et al. 2023). Similarly, accidental entanglement in fishing gear is an important source of (subadult) Mediterranean monk seal mortality (Karamanlidis et al. 2020). Negative interactions with fisheries appear to still be a serious conservation threat in Türkiye as well, e.g. in the Muğla Province (Ateş et al. 2019) and in the northeastern Mediterranean coast of Türkiye (Yiğit et al. 2018). The deliberate killing of Mediterranean monk seals has been recorded on several occasions recently (Danyer et al. 2013, 2014, 2018), while at least 14 Mediterranean monk seals have died from entanglement in fishing gear in the Turkish Aegean and Mediterranean Sea (SAD—AFAG unpubl. data in Karamanlidis et al. 2023). Although not currently an issue, negative interactions with fisheries could become one in the Republic of Cyprus (Papageorgiou et al. 2023), where the species has recently been successfully re-established. The impact of this threat on the recovery prospects of the species is vividly exemplified by the pregnant female Mediterranean monk seal that was deliberately killed in Lebanon (Bariche & Crocetta 2016) and the subadult seal that drowned in a net in Libya (Alfaghi et al. 2013).

4.3. Unpredictable threats

Unpredictable threats, such as cave collapses (e.g. Cabo Blanco, González et al. 1997) and mass mortality events, such as the one that occurred in 1997 in Cabo Blanco (Forcada et al. 1999) caused by toxic algal blooms or epizootic outbreaks (Johnson et al. 2006, Karamanlidis et al. 2016a), could potentially have detrimental effects on a species with a small global population size such as the Mediterranean monk seal (Karamanlidis et al. 2023). These threats are particularly important in the northeastern Atlantic because of the limited geographical range of the species in the region.

4.4. Pollution

Pollution has been suspected to pose a medium threat to the Mediterranean monk seal, affecting either the habitat or the species itself (Johnson et al. 2006, Karamanlidis et al. 2016a). Habitat pollution, either in the form of oil spills and other ship accidents and groundings or the accumulation of solid waste in

critical habitat, is still a pertinent threat to the Mediterranean monk seal, especially in the eastern Mediterranean subpopulation. Regarding oil spills, 3 accidents have affected critical Mediterranean monk seal habitat in Türkiye (Kıraç et al. 2022), resulting in one clean-up operation and the establishment of regulatory measures to minimize the impact of this threat (Kıraç & Güçlüsoy 2007). Accumulation of solid waste negatively affecting suitable Mediterranean monk seal habitat has been recorded in Greece, Türkiye and Cyprus and has been remediated with clean-up operations (Dendrinis et al. 2015).

Research in the 1990s on the effects of organochlorine pollutants on Mediterranean monk seals in the Cabo Blanco and the eastern Mediterranean subpopulation has indicated that residue levels were very low in the former subpopulation and moderate to high in the latter (Johnson et al. 2006, Karamanlidis et al. 2016a). More recently, preliminary efforts have been carried out to evaluate the effects of polycyclic aromatic hydrocarbons (Marsili et al. 2014) and trace elements in Mediterranean monk seals in Greece. Regarding the latter, results indicate that although potentially adverse effects on the immune and endocrine system of Mediterranean monk seals from some pollutants (e.g. As, Cd, Se, Ni, Cr) cannot be ruled out, pollution levels in Greece are generally low and within non-acutely toxic levels for pinnipeds (Formigaro et al. 2017). Similar research in the archipelago of Madeira indicates that pollution levels at this remote oceanic island are even lower than in Greece (McIvor et al. 2022). Finally, increased efforts have been invested recently to evaluate the emerging threat of microplastics to the Mediterranean monk seal. Preliminary studies in Albania (Bundone et al. 2022), Greece (Pietroluongo et al. 2022a, Hernandez-Milian et al. 2023) and the island of Madeira (McIvor et al. 2023) indicate a high concentration and variety of microplastics in the digestive systems of Mediterranean monk seals.

4.5. Other sources of mortality — potential threats

Finally, additional sources of mortality that have been recorded include reports of past predation by a white shark *Carcharodon carcharias* on an adult Mediterranean monk seal in the Balearic Islands (Pujol 2015), suffocation of a juvenile Mediterranean monk seal trying to feed on an octopus in Greece (Kapiris et al. 2018) and the death of a Mediterranean monk seal in northern Cyprus while feeding on the toxic silver-cheeked toadfish *Lagocephalus sceleratus* (Gücü pers. comm. in Karamanlidis et al. 2023).

Potential threats, such as genetic inbreeding and climate change (i.e. sea level rise that could reduce critical beach habitat inside important marine caves [Fernández de Larrinoa et al. 2021], thus inducing further habitat loss and degradation) could also negatively affect the Mediterranean monk seal; currently, not enough information is available to fully evaluate the magnitude of these threats.

5. CONSERVATION PRIORITIES AND ACTIONS

The Mediterranean monk seal is legally protected by numerous national laws and regional (Notarbartolo di Sciara 2013) and international treaties (e.g. the Convention on International Trade in Endangered Species of Wild Fauna and Flora, the Convention on the Conservation of Migratory Species of Wild Animals, the Convention on the Conservation of European Wildlife and Natural Habitats, the Convention on Biological Diversity, the United Nations Convention on the Law of the Sea), as well as European Union (EU) regulations (e.g. Council Directive 92/43/EEC-Natura 2000 on the Conservation of Natural Habitats of Wild Fauna and Flora, Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008). Furthermore, and within the EU (i.e. Greece, Cyprus and Portugal), habitat protection is offered through Council Directive 92/43/EEC and the Natura 2000 Network of Protected Areas, which, in the case of the Mediterranean monk seal subpopulation in the archipelago of Madeira, includes all the important caves for the species in the region (Pires et al. 2020). Within this legal framework, most countries within the range of the Mediterranean monk seal have already identified conservation priorities and are carrying out priority conservation actions that have been included in local and/or national (e.g. archipelago of Madeira, Pires et al. 2020; Greece, Dendrinis et al. 2020; Türkiye, Kıraç et al. 2013) and regional (e.g. Adriatic Sea, Panou et al. 2023; Mediterranean Sea, Notarbartolo di Sciara 2013; Eastern Atlantic, González et al. 2006) action plans for the protection of the species.

Following the conservation priorities identified in the Action Plan for the recovery of the Monk Seal in the Eastern Atlantic Ocean (González et al. 2006), efforts to protect the Mediterranean monk seal in Cabo Blanco have included the permanent protection and monitoring of critical terrestrial and marine habitat, the standardized scientific monitoring of the subpopulation, the development of a social aid program

to improve the livelihood of local coastal fishermen as well as the implementation of a widespread public awareness and education program. Within the framework of the same action plan (González et al. 2006), legislative measures and research, management and conservation actions to effectively protect the Mediterranean monk seal in the archipelago of Madeira have been implemented since 1988 (Pires et al. 2020). Recent conservation efforts have included the standardized scientific monitoring of the subpopulation and its habitat, the mitigation of negative seal–fishery interactions, public awareness and habitat protection (IFCN unpubl. data in Karamanlidis et al. 2023). In 2020, the Strategy for the Conservation of the Mediterranean Monk Seal was approved by the Government Council of Madeira (Pires et al. 2020). In Greece, conservation priorities for the Mediterranean monk seal have been established within the recently proposed Action Plan for the Mediterranean Monk Seal (Dendrinos et al. 2020), which describes in detail actions that should be carried out in the country until 2027 in order to safeguard the future of the species. This action plan highlights the importance of the scientific monitoring of the species, the protection of critical terrestrial and marine habitat as well as the special importance of rehabilitating Mediterranean monk seal pups and mitigating negative seal–fishery interactions. Since 1990, more than 29 pups have been rehabilitated in Greece, where an individually tailored medical programme has been established to treat animals. After reaching a certain age and weight, at least 14 seals have been safely released back to the wild (Komnenou et al. 2019), positively affecting neonatal survival rates for the Mediterranean monk seal in the country. Regarding the latter, specific and general local and nationwide fishery management and conservation actions have been proposed, aimed at improving the overall status of fish stocks and changing the behaviour of fishers, while at the same time improving the conservation status of the species in the country (Karamanlidis et al. 2020). In Türkiye, conservation priorities for the Mediterranean monk seal have been defined in the national action plan (Kıraç et al. 2013), based on which nationwide conservation and public awareness and educational efforts have been ongoing for more than 3 decades. Conservation activities have included the protection of critical terrestrial and marine Mediterranean monk seal habitat (i.e. including the prohibition of the illegal entering into marine caves and a clean-up operation after an oil spill), scientific monitoring of the species, rescue and rehabilitation of seals and widespread public awareness and educa-

tional activities. These actions have been carried out primarily in the 4 provinces of İzmir, Muğla, Antalya and Mersin and 5 coastal locations (i.e. Gökçeada, Foça-Karaburun, Alaçatı-Sığacık, the Bodrum Peninsula and the Cilician coasts) that have been adopted as monk seal priority conservation zones (Kıraç et al. 2013). In the Republic of Cyprus, the Mediterranean monk seal has been legally protected since 1971 by the Fisheries Law and Regulations. Research (i.e. including intense population monitoring efforts), effective management and protection of critical terrestrial and marine habitat for the species (i.e. including habitat restoration efforts) and public awareness and education are some of the conservation measures currently implemented to effectively protect and conserve the Mediterranean monk seal in Cyprus; the development of a national action plan and a national monitoring protocol are considered a priority for the species in the country (Department of Fisheries and Marine Research Cyprus pers. comm. in Karamanlidis et al. 2023).

In summary and on a global scale, priority conservation actions for the Mediterranean monk seal include (Karamanlidis et al. 2023) (1) strengthening the legal framework for the protection of the terrestrial and marine habitat of the species, especially in the area of Cabo Blanco; (2) effective protection of the species (i.e. reduction of deliberate killing) and its terrestrial and marine habitat; (3) scientific population and habitat monitoring (including, for example, estimating population demographics and vital rates and determining food availability and primary causes of death); (4) rescue and rehabilitation of injured, orphaned and sick individuals to increase neonatal survival rates; (5) public awareness and education, (6) monitoring and mitigating negative seal–fishery interactions; and (7) expansion of the species' current geographic range in the Atlantic Ocean (González et al. 2006, González 2015). In 2022, the signatory countries to the Action Plan of the Monk Seal in the Atlantic committed to the creation of a network of subpopulations in the eastern Atlantic (P. Fernandez de Larrinoa pers. comm.). All these priority conservation actions need to be pursued with vigour and systematically in order to ensure that the recovery of the Mediterranean monk seal continues in the years to come.

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Editorial responsibility: Brendan Godley,
University of Exeter, Cornwall Campus, UK
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